Fig. 1 Chain VV172 of five galaxies.

Observational Paradoxes in Extragalactic Astronomy (*)

J. Schneider, Meudon

Chargé de Recherches at the CNRS, working in the Groupe d'Astrophysique Relativiste, at the Meudon Observatory, Meudon. France.

Certain extragalactic observations, because of their paradoxical aspects constitute a great mystery to astronomers. These observations, which still need confirmation, do not fit the current picture of the Universe. In particular, the puzzle due to the observed redshifts of some galaxies and quasars for which at present there is no explanation will be considered here.

Today's conventional cosmology rests on the empirically derived expansion law of Hubble which gives for the redshift of galaxies and quasars

$$z \equiv \lambda'/\lambda - 1 = HD/c \quad (1),$$

where λ is the value of the wavelength of spectral lines at the emission and λ' is their value at the observer ; H is the present day value of the Hubble constant, D is the present distance and c is the velocity of light. The product zc is the symbolic recession velocity, designated often shortly as redshift.

Here it is important to realize that measuring the distance is very difficult. For a quasar (QSO) no distance measurement has so far been possible. It is assumed however that the above relation holds for these objects.

To understand astrophysical phenomena the following basic working hypothesis is made, i.e. the present laws of microscopic physics are the same in a celestical body as those we know today on the Earth. One can call this the *Fundamental Hypothesis of Astrophysics.*

With this the whole Universe is described and one could in principle stop here. In fact, it is at this point that things start.

For several years it has been known that a few groups of galaxies present the curious property that the redshift of one galaxy differs greatly from that of the others :

in the *Chain VV 172* (Fig. 1) the galaxy B has a redshift of 30 000 km/s whereas the four other galaxies have redshifts of 15 000 km/s ; in the *Seyfert Sextet* one galaxy has a redshift of 20 000 km/s whereas the five other redshifts are 4 500 km/s ; in *Stephan's Quintet* (Fig. 2) the galaxy A has a redshift of 800 km/s whereas the others have redshifts of 6 000 km/s.

How can such large differences be explained by conventional cosmology as summarized in eq. (1) ? Certainly not by orbital motions of the objects around each other since the escape velocities are of the order of 500 km/s. By the term HD/c ? But then one must conclude that these galaxies are so close together in the sky as a result of chance only. From the density of galaxies in the sky, one estimates the probality to be very small that three coincidences occur.

Astronomers became aware of these curiosities at about the same time as the discovery of QSO's. At that time the cosmological origin of the redshift of quasars was questioned. A few astronomers assumed that there might exist a different origin to the redshift than the Doppler effect and the cosmic expansion. To check whether different galaxies were at the same distance and thus that their cosmological redshifts where the same, H. Arp studied galaxies connected by luminous filaments. He found that even two objects connected by a bridge could have very discrepant redshifts. In Fig. 3, where the connection is well established, the large galaxy has a redshift of 8 000 km/s and the compact companion a redshift of 19 000 km/s. There exist five other possible connections between galaxies and compact objects (see table I). The largest difference is found for the pair NGC 4319/M205 (Fig. 4) where the galaxy has a redshift of 2 000 km/s whereas the compact object (a QSO or a N-type galaxy) has a redshift of 20 000 km/s. However these latter connections are not definitively confirmed and a large part of the controversy concerns their existence.

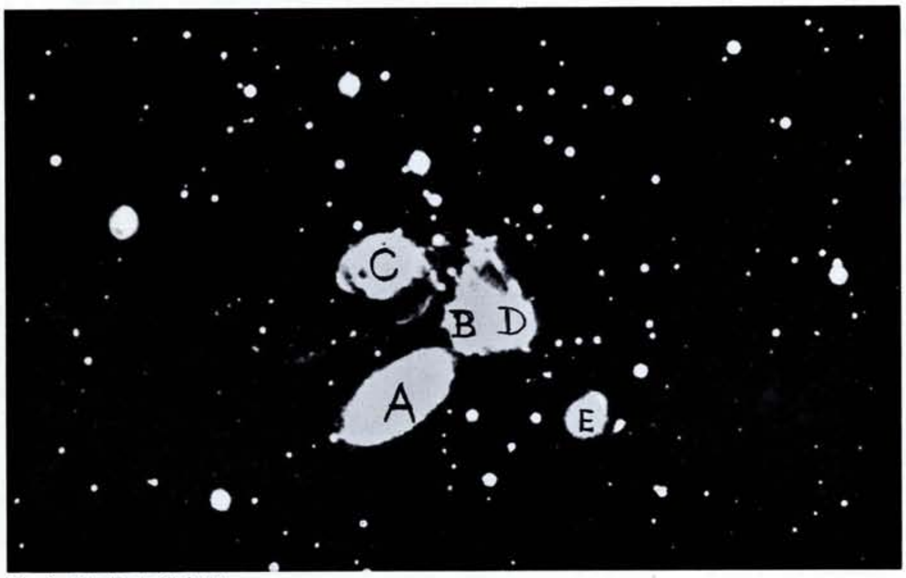

Fig. 2 Stephan's Quintet.

* Seminar given at CERN, Geneva on 12 February 1974.

Fig. 3 Galaxy NGC 7603 (redshift 8 000 km/s) connected by a bridge of luminous matter to a compact companion at the bottom (redshift 19 000 km/s).

For NGC 4319/M205 Arp obtained six photographs with a visible connection but other observers did not succeed in seeing the bridges. When two objects with different redshifts are connected one can ask whether it is the high redshift object or the low redshift one which does not satisfy the Hubble relation (1). What is remarkable is that whenever it was possible to make a decision it was the high redshift object that did not follow the law.

Let us now return to the *Stephan's Quintet* which I mentioned at the beginning. Here it was possible to go one step further since the distance of the galaxies has been determined. First Arp has determined the distribution of the angular size of the H_{II} regions of galaxies A and B (Fig. 2). H_{II} regions are large spheroïdal sources of ionized hydrogen and their angular diameter gives a distance indication. The distance of galaxy A measured in this way agreed with the Hubble distance deduced from Hubble law. Surprisingly however the distance of galaxy B turned out to be about the same than that of galaxy A, disagreeing thus completely with the Hubble distance since the redshift of that galaxy is 8 times larger. On the other hand a group of radioastronomers from the Meudon Observatory made a distance determination based on a different method, i.e. on a statistical and empiral correlation between the absolute luminosity L and content M in neutral hydrogen of a galaxy of given type. Here again the distance of the galaxy A measured in this way was in agreement with the Hubble distance; and here again the distance of a high redshift member of the group, galaxy C, turned out to be in complete disagreement with the Hubble law.* Moreover the discrepant shift which was at first sight the low redshift in the Quintet turned out to be in fact the high redshift ; thus the hypothesis that anomalous shifts were towards the red was strongly confirmed. Since the extra redshift can not be absorbed by any orbiting or ejection velocity nor by a gravitational origin, one has to find something new to explain redshift. Some astronomers, like Arp, have proposed to give up the Fundamental Hypothesis and envisaged that new physical laws applied in celestical bodies.

Theoreticians also have speculated about new theories to explain these observations. One line of sought due to Hoyle and Narliker assumes that the electron rest mass is not an abso-

Fig. 4 Galaxy NGC 4319 connected by a luminous bridge to quasar M 205 whose redshift is ten times larger. The real existence of the bridge is still controversed.

TABLE I

Galaxy	zc	Connected object	zc
N 7603	8 000 km/s	anonymous	19 000 km/s
N 7320	800	N 7320 C	6 000
N 4151	900	N 4156	6 000
IC 3483	100	IC 3483	7 000
N 4319	2 000	M 205	20 000
Anonymous	< 100 000 ?	PHL 1226	120 000

* *See note on page 8.*

lute constant but changes from place to place in the Universe. Such a change would shift the energy levels of atoms and thus the transition frequencies. This assumption however does not explain why the shift is systematically towards the red. Another attempt was made by J.-C. Pecker, J.-P. Vigier et al. from Paris: they assume a new type of inelastic interaction between the photon and a new massive boson. In these interactions the photon would loose an energy $\Delta E = h \Delta \nu$ and thus be redshifted. This explanation has for the moment no sound theoretical foundation and moreover is rather ad hoc; for example, it does not explain why galaxies from the *Stephan's Quintet* are so much redshifted while other very similar galaxies are not. So there is no satisfactory explanation and the mystery remains complete.

But is there a hope to cut the Gordian knot? Are we condemned to stay with these few observations and remain unable to draw a conclusion? Fortunately not. Several new observations are possible, namely to confirm or to infer from new techniques the connections listed in Table I and to determine by the methods mentioned above or by other ones, the distances of the galaxies having a discrepant redshift.

* Note from the author:

This last method has very recently been applied to galaxy B. The result is in agreement with the Hubble law and thus in contradiction with the measurement of Arp.

Meetings

For a full list of events see the latest Meetings Issue of *Europhysics News* **5,** 5 (May 1974). Notification of the meetings announced in this issue has been received recently.

The order of information is: date, title, venue, and contact for information.

Conferences 1974

26 - 27 September
Interdisciplinary Symposium on the Measurement of Molecular Oxygen
Odense, Denmark
H. Degn, Institute of Biochemistry, Odense University, Niels Bohrs Alle, DK - 5000 Odense

29 September - 3 October
6th Bulgarian Conference on Spectroscopy
Sunny Beach, Burgas, Bulgaria
Organizing Committee of 6th Bulgarian Conference on Spectroscopy, 72, Boulevard Lenin, Sofia 13

18 - 20 November
4th All Union Accelerator Conference
Moscow, USSR
A.L. Mintz, Committee Chairman, USSR Academy of Sciences, Leninskiy Prospekt 14, Moscow B - 71

16 - 20 December
Light Scattering Studies of Motion in Molecular Systems
Verbier, Switzerland
E. Courtens, IBM Research Laboratory, Säumerstrasse 4, CH-8803 Rüschlikon

1975

24 - 26 March
Nuclear Interactions at Medium and Low Energies
Harwell, UK
The Meetings Officer, The Institute of Physics, 47, Belgrave Square, London SW1X 8QX

21 - 25 April
First European Nuclear Conference — The Maturity of Nuclear Energy
Paris, France
P. Zaleski, European Nuclear Society, B.P. No. 27, F-92140 Clamart

June
Molecular Energy Transfer
J.P. Toennies, Max-Planck-Institut für Strömungsforschung, 6-8, Böttingerstrasse, D-34 Göttingen, Fed. Rep. Germany

3 - 7 June
5th International Conference on Atomic Masses and Fundamental Constants (AMCO - 5)
Paris, France
P. Grivet, AMCO-5, Institut d'Electronique Fondamentale, Bâtiment 220, Université Paris-Sud, F-91405 Orsay

16 - 18 July
3rd International Seminar on Ion-Atom Collisions (ISIAC)
Stanford, Cal., USA
F.T. Smith, Stanford Research Institute, Menlo Park, Cal. 94025

24 - 30 July
9th International Conference on the Physics of Electronic and Atomic Collisions (ICPEAC)
Seattle, Wash., USA
R. Geballe, Department of Physics, University of Washington, Seattle, Wash. 98195

18 - 21 August
3rd International Conference on Vapour Growth and Epitaxy
Amsterdam, The Netherlands
C.J.M. Rooymans, Philips Research Laboratories, Bldg. WA, Eindhoven

18 - 22 August
12th International Conference on the Phenomena in Ionized Gases
Eindhoven, The Netherlands
F.J. de Hoog, Technische Hogeschool Eindhoven, P.O. Box 513, Eindhoven

25 - 29 August
3rd International Conference on Thin Films — Basic Problems, Applications and Trends
Budapest, Hungary
Organizing Committee ICTF-3, P.O. Box 76, H-1325 Budapest

25 - 29 August
International Conference on Statistical Physics
Budapest, Hungary
P. Szépfalusy, Institute for Theoretical Physics, Eötvös University, Puskin u. 5-7, H-1088 Budapest

'Summer' Schools 1974

15 - 20 September
Thermal Neutron Scattering
Harwell, UK
B.T.M. Willis, Atomic Energy Research Establishment, Harwell, Didcot, Oxfordshire

15 - 25 September
Workshop on Weak Interactions with Very High Energy Beams
St. Wolfgang, Austria
H. Pietschmann, Institut für theoretische Physik, Boltzmanngasse 5, A-1090 Vienna

30 September - 3 October
Charge Transfer Devices
Heverlee, Belgium
E. Laes, C.T.D. Course, Laboratorium Fysika en Elektronika van de Halfgeleiders, Kardinaal Mercierlaan 94, B-3030 Heverlee

1975

28 July - 5 August
International Summer School on Crystallagraphic Computing
Prague, Czechoslovakia
F.R. Ahmed, Division of Biological Sciences, National Research Council of Canada, Ottawa, Canada K1A 0R6

Editor: Lorette Etienne-Amberg.
Editorial Advisory Panel:
G.J. Béné, B. Giovannini, G. Harbeke, E.N. Shaw, J.J. Went.
All correspondence to:
Editor, EUROPHYSICS NEWS, European Physical Society, P.O. Box 39, CH - 1213 Petit-Lancy 2
Phone: Geneva 93 11 32
Switzerland.
Published by the European Physical Society
Printed by: Ed. Cherix et Filanosa S.A. CH - 1260 Nyon, Switzerland.